1/PRTS

An apparatus for the continuous melting and refining of anorganic compounds, especially glasses and glass ceramics

The invention relates to an apparatus for the continuous melting and refining of anorganic compounds, especially glasses or glass ceramics. Other substances can also be considered.

Numerous apparatuses have become known with which the said materials can be molten or refined, e.g. DE 33 16 546 C1. This concerns a so-called skull crucible with a cooled crucible wall and further with an induction coil which encloses the crucible and can be coupled into the crucible content by way of high-frequency energy. It allows bringing the crucible content to exceptionally high temperatures which reach up to 3000°C.

The advantage of high-frequency heating is that the crucible wall can be considerably colder than the glass melt. The cooling of the crucible wall can be performed through heat dissipation or active air or water cooling. In the skull crucible, a cold crust of generic material is formed in the wall zone. This crust has very low electric conductivity due to the lower temperature. That is why it does not absorb any high-frequency energy and forms a stable generic crucible. It thus allows reaching virtually any high melt temperature. It must merely be ensured through sufficient cooling that the generic wall is maintained (see EP 0 079 266 for example).

The melting process must usually be followed by a refining process. The refining is usually employed to free the molten glass of physically and chemically bound gases. The refining process is supported by special refining agents such as NaCl for example. The refining agents make a contribution in the respect that sufficiently large gas bubbles can form into which the residual gases from the melt can diffuse.

Lately, the demand has increasingly been made to operate the process of melting on the one hand and the process of refining on the other hand in a continuous way. WO 92 15531 describes an apparatus in which the melting and the refining occur in one and the same crucible. The two processes cannot be controlled independent from one another, which has an adverse effect on the glass quality.

The apparatus can merely be used for producing glasses with lower requirements placed on the quality. Moreover, the refining in this apparatus shows low effectiveness because cold starting material is continuously re-supplied in the surface area of the melt and the surface will always be the coldest part in the crucible.

US 4 780 121 describes an apparatus in which a first vessel is provided in which the mixture is molten and a second vessel in which the refining of the molten glass mass is performed. The glass melt as produced in the melting crucible is supplied from above to the refining vessel. The ceramic refining vessel is enclosed by an induction coil by means of which high-frequency energy can be coupled into the refining vessel. As a result of the ceramic refining crucible, the generation of high temperatures in the refining vessel is limited. The result of the refining is unsatisfactory in this apparatus. Even after the refining gas remains in the glass melt, namely to an extent which impairs the quality of the end product in an unacceptable manner.

A further disadvantage of this apparatus is the following: In order to enable the apparatus to be operated continuously, the throughput through the melting crucible must be as high as the throughput through the refining vessel. The progress of the processes in the two vessels is subject to different parameters, however. Accordingly, the temperature in the refining vessel must be adjustable to the refining process. It can thus not be

chosen freely. The method which can be performed with this method comes with the disadvantage that a regulation of the glass flow is not possible. The glass level can only be influenced by changing the outlet opening in the melting unit. A regulation or even only a control of the glass flow from the HF zone to a conditioning tank independent of the refining temperature is not possible. The discharge speed depends on the temperature in the HF crucible zone. If the temperature changes in the HF zone, the discharge increases due to the low viscosity of the melt. As a result, dramatic limitations concerning the possibilities of temperature variation are thus predetermined. Higher temperatures in the refining zone can at best be set in combination with a throughput increase. As a result, the advantage of improved refining by increasing the temperature is destroyed by the lower dwell time. Moreover, the free glass fall into an HF refining section leads to the disadvantage that bubbles can be shot in. Such shot-in air bubbles contain high shares of nitrogen and can thus be refined only with difficulty. This problem applies even more in the transfer from the HF zone to the homogenization zone. Bubbles that are shot in here are no longer able to leave the melt because no refining is performed here.

The invention is based on the object of providing an apparatus in which the melting on the one hand and the refining on the other hand are each performed in a separate vessel, which can further be operated in continuous operation, and in which the refining in particular leads to a perfect result, i.e. to a substantial degassing.

This object is achieved by the features of claim 1.

The inventors have recognized the following:
As explained above, the refining vessel is provided downstream of the melting vessel in the apparatus according to US 4 780 121 and it is

disposed below the same. The liquid melt thus flows into the refining vessel in free fall. The incoming melt is thus relatively cold. The surface of the content of the refining vessel is thus continuously formed by in-flowing cold melt. The major part of the cold and thus heavy glass melt flows into the middle of the refining crucible and rapidly to its outlet. The degassing occurs in the floor zone of the refining vessel, however, because heating by the induction coil can become effective there to a higher extent that in the surface zone. The gas bubbles are thus formed in the floor zone. Although they rise upwardly, the gas bubbles are prevented from continuing to rise and leave the melt by the relatively high viscosity of the cold layers in the top level zone. This means that gas remains to an undesirable extent in the melt contained in the refining vessel.

These disadvantages are avoided by the invention. The relatively cold melt emerges from the lower zone of the melting vessel, is introduced in the floor of the refining vessel and heated there by HF energy. Bubbles are formed by the gases contained in the melt. The bubbles rise upwardly. Since the upper layers of the melt are relatively hot and are thus of lower viscosity, the gas bubbles are able to leave the melt with ease.

The application of the invention allows bringing the content of a high-frequency heated skull crucible without a ceramic internal crucible to temperatures in the magnitude of 2400°C to 2600°C, and even to 3000°C. This is particularly important during the refining. The glass is relieved of physically and chemically bound gases in this process. The refining process is supported by refining agents such as Na_2So_4, As_2O_3, Sb_2O_3 or NaCl. These refining agents decompose or evaporate at refining temperature and form bubbles into which the residual gases from the melt can diffuse. The refining bubbles must be sufficiently large in order to rise within economically viable intervals to the surface of the glass melt and burst there. In the mentioned high temperatures which are achieved by the

invention, the rising speed is very high. The rising speed increases in the case of a temperature rise from 1600°C to 2400°C by a factor of 100. A bubble with a diameter of 0.1 mm thus rises at a temperature of 2400°C as fast as a bubble with a diameter of 1 mm at a temperature of 1600°C.

The physical and chemical solubility is reduced in most gases by an increase of the refining temperature and thus the high-temperature refining is supported.

As an alternative to increase the rising speed of bubbles and thus to reduce the refining time, the addition of refining agents can be omitted to a more or less strong extent. The precondition is, however, that the rising gas can reach the surface and that the bubbles located at the surface will burst and that no foam will be formed.

The principle in accordance with the invention has a further advantage. Due to the fact that the melt flows into the refining vessel from below, namely in the floor zone, the jacket surface of the refining vessel is essentially free from connections. In this way the induction coil can be arranged in an unobstructed way and without having to take any spatial considerations into account such that it encloses the jacket surface of the refining vessel at will, as is desirable under the aspect of optimal coupling-in of high-frequency energy.

The invention is now explained in closer detail by reference to the drawing.

A melting vessel 1 is shown. It is arranged as a walled trough made of ceramic material. A connecting line 2 is used to supply the glass melt produced in the melting vessel 1 to a refining vessel 3. The refining vessel 3 is associated with an induction coil 5. The induction coil 5 encloses the

refining vessel 3 in a manner that the windings of coil 5 enclose the vertical axis of the refining vessel 3 in a substantially concentric way.

A horizontal groove 4 is connected to the refining vessel 3. It is used for cooling the melt. The cooling is performed here from high temperatures, e.g. from the range of 2400 to 3000°C to a temperature of 1600°C. The cooling groove can consist either of a stone or ceramic groove which is air or water-cooled, or of a high-frequency heated skull groove. A post-refining and the resorption of the residual bubbles can be made in the cooling groove.

A stirring crucible 6, with a stirrer 6.1, is disposed at the end of the groove for homogenizing the melt. The melt is taken from the stirring crucible 6 via a feeder 6.2 in order to be supplied to the shaping process. The groove 4 is associated with a glass level gauge 7 with which the geodetic height of the level of the glass melt in the groove 4 can be detected.

The melting in the melting vessel 1 can be performed both electrically as well as with burners or by a combination of the two means. The so-called raw melt occurs in the zone of the melting vessel.

The connecting line 2 consists either of a resistance-heated platinum pipe or of refractory material. If the connecting line 2 consists of refractory material, then glass melt is heated directly by using electrodes. Alternatively, the heating can also be performed from the outside.

As is shown, the connecting line 2 is connected in the lower zone to the melting vessel 1. It passes through the floor 3.1 of the refining vessel 3 into the same. The glass leak-proofness at the connecting point is achieved by an annularly arranged water or air cooling. This seal, which usually consists of platinum, is also simultaneously used as a high-frequency screen. It is

electrically shunted to ground potential. This prevents high-frequency leakage radiation from being led out of the high-frequency zone through the connecting line 2 and through the electrodes to where the open-loop and closed-loop control of other electric components can be disturbed. If necessary, glass sealing and electric grounding can be installed separately from one another.

The refining vessel 3 per se is arranged modularly and thus very flexibly. It consists of several segments with meandering water-cooled copper or stainless steel pipes. The segments are electrically short-circuited in the floor zone in order to prevent the formation of any arcs between the segments at very high melt temperatures. This can occur for example when the insulation crust of the generic material becomes very thin. A short circuit is also possible in the upper zone of the refining vessel 3. Disadvantageous is the displacement of the high-frequency field to the lower zone of the refining vessel, because this can lead to a cooling of the melt surface.

At refining temperatures of up to 1650°C, the refining tank can also consist of a ceramic material. The high frequency must not couple into the ceramic material because otherwise the tank would be molten by the high frequency. Ceramic tanks have the disadvantage that, as a result of heat radiation, the air between the tank and the high-frequency coils can heat up to such an extent that an arc-over may occur. The skull crucible is usually more advantageous for refining temperatures of over 1650°C because in this way the crucible wall can be cooled intensively by water- or air-cooled metal pipes. Virtually any desired high refining temperature can be achieved with the skull crucible because the maximum refining temperature is not limited by crucible corrosion.

The melting volume of the refining crucible 3 is chosen in such a way that the dwell time for the required refining result is just sufficient. Any over-dimensioning must be avoided from an energetic point of view. The cooling of the thus linked larger wall losses must be compensated by additional high-frequency output. It has been seen for alumosilicate glasses for example, that for the refining, a dwell time of 30 to 60 minutes at refining temperatures of 2200°C for example is sufficient.

The melting vessel is walled with refractory material, as explained above. Instead, it could also be arranged as a skull crucible. In this case it has the same structure as the refining vessel with an induction coil for coupling-in high-frequency energy into the content of the vessel, as described here.

As a result of the arrangement according to the principle of interconnected pipes, the regulation of the glass level is very simple. The measurement of the glass level is performed in the conventional melt zone of the groove (shortly before the stirrer). Since all components are connected with one another, the glass level in the entire melting unit is known. The measured variable from the tank end can be used for controlling the entire glass level, from the melting tank, via the HF refining section up to the groove.

This simple control of the glass level is possible because it has been managed here to integrate the HF refining section in the system of the tank as an interconnected component. The throughput can be regulated completely independent of the HF refining temperature and the viscosity in the refining unit.

At the end of the groove there is a stirring crucible (6) for homogenizing the melt. The glass is taken from the tank via a feeder (7) and supplied to the shaping process.

The melting vessel (1) and/or the refining vessel (3) can be arranged within a conductive cage for protection from the re-radiation of the electromagnetic field produced by the high-frequency device.